Energy Conservation and Transformation

Next Generation Science Standards

NGSS Science and Engineering Practices:

- ☑ Asking questions and defining problems
- ☐ Developing and using models
- ☑ Planning and carrying out investigations
- ☑ Analyzing and interpreting data
- ☐ Using mathematics and computational thinking
- ☑ Constructing explanations and designing solutions
- ☐ Engaging in argument from evidence
- ☑ Obtaining, evaluating, and communicating information

NGSS Cross-cutting Concepts:

- ☐ Patterns
- ☐ Cause and effect
- ☐ Scale, proportion, and quantity
- ☐ Systems and system models
- ☑ Energy and matter
- ☐ Structure and function
- ☑ Stability and change

NGSS Disciplinary Core Ideas:

- ☑ PS2.A: Forces and Motion
- ☑ PS3.B: Conservation of Energy and Energy Transfer

Initial Prep Time

Approx. 10 min. per apparatus

Lesson Time

1 – 2 class periods, depending on experiments completed

Assembly Requirements

- Scissors
- Small Philips screwdriver

Materials (for each lab group):

- Horizon Fuel Cell Car Science Kit
- Distilled water
- AA batteries
- Stopwatch
- Horizon Renewable Energy Monitor or multimeter (optional)

Energy Conservation and Transformation

Lab Setup

- Be sure to set aside enough time to assemble your fuel cell cars before starting this activity. You'll need AA batteries, scissors, a ruler, a small Philips-head screwdriver, and plenty of distilled water to assemble the cars. See the Fuel Cell Car Science Kit Assembly Guide for complete assembly instructions.
- Please note that the PEM fuel cell's membrane should be kept from drying out. It's best to seal it in a plastic bag between uses. Before students use the cell, be sure it's filled with water and that the two small pieces of tubing are attached.
- Some of the parts of the car are quite small (such as tube caps) and can be lost easily. Setting up resource areas on lab tables with labeled containers for each group's pieces can prevent loss of these small parts and help keep the parts of each group's kit separate.
- If you don't have access to a multimeter or Horizon Renewable Energy Monitor, omit the Measurements section of this activity.
- Feel free to skip particular experiments or questions based on available class time.

Safety

- Battery packs can short out and heat up if the red and black contacts touch each other while the unit is in the on position. Be sure to keep them off when not in use.
- Using regular tap water instead of distilled water will severely shorten the lifespan of the fuel cells. Distilled water can be found at most pharmacies or drug stores.
- Running electric current through dry fuel cells or attaching the battery packs backwards can destroy the fuel cells. Be sure to always connect red to red and black to black.
- Beware of water spills, and don't be surprised if someone tries to start a syringe water fight.

Notes on Fuel Cell Cars

- The car's front wheels may not touch the ground if the motorized wheels stick out too much, but that shouldn't affect the car's performance.
- Though the car can detect and steer around objects that it bumps into, it won't detect the edge of a table. It may be best to put them on the floor when it's time to have them run.

Common Problems

- If performance decreases, purge your fuel cells by opening up the tube caps to allow trapped air to escape.
- If the water level doesn't change after purging the cells, make sure the gaps on the base of the inner cylinders are open so that water can fill them.

Energy Conservation and Transformation

Goals

- Understand how energy can change
- Observe the transformation of energy
- Make calculations based on data

Background

Energy is what allows all objects in the universe to move. The energy of atoms or molecules and the energy of stars or galaxies is all the same, just at different sizes. Though we talk about energy being consumed, lost, or used up, it can never be destroyed. It can also never be created. The only thing that energy can do is transform from one kind to another.

Using this fuel cell car, we can use the chemical potential energy of hydrogen to create electrical energy, which will be turned into kinetic energy to cause the car to move. But there are other ways that energy is transformed, even in this small car, which mean that not all the energy in each transformation remains in a useable form.

Thermal energy is an example of a type of energy that isn't always useful. Though we can use it for some applications, such as cooking food, the transformation of different kinds of energy into heat energy is usually a bad thing for most machines.

In the case of a car, more heat energy means less kinetic energy, so a smaller percentage of the energy put into the car is used to actually run it.

Fuel cells are much more energy efficient than the internal combustion gasoline engines that power most cars today, but they still have their sources of inefficiency.

Procedure

1. Once the fuel cell starts producing hydrogen and oxygen gas from water, we will need to trap the gases to be able to use them for the reverse reaction. How can the gases be trapped using the materials provided?
2. The Oxygen side of the fuel cell needs to be filled with water. Observing the hydrogen fuel cell, why do you think only one side needs to be filled with water? Do you think it matters if the water is injected into the top or bottom outlet?
3. How can we tell how much gas has been generated from our reaction?
4. Does it matter how the battery pack is attached to the fuel cell? Why or why not?
5. If you're ready to capture the gases produced by the fuel cell, attach the battery pack. Observe what happens and record your observations below.

Energy Conservation and Transformation

Observations

Experimentation

1. You've produced hydrogen and oxygen from water. Now, connect the fuel cell to the motor. What happens?

Students should notice the motor begins to run and can make note of any particular aspect of the car's performance: sound of the motor, the flashing LEDs, when the car turns or backs up, how long it runs, etc.

2. What could you change about your car that might make the car run faster? Try it and observe what happens.

Using less water in the cylinders to decrease weight, running the car on a different surface, decreasing friction, and others may be acceptable answers.

3. What if you wanted to make your car run for a longer time? Would you change the same thing or something different? Try it and observe what happens.

Answers may differ from the previous question, but some may be similar. However, it should be noted that to make the car run longer it could also have bigger fuel tanks, generate more hydrogen, or be picked up so that the wheels spin freely.

Energy Conservation and Transformation

Measurement

For this section, you will need a multimeter or the Horizon Renewable Energy Monitor. For an introduction to using a multimeter, click here.

1. Measure the current in Amps and the voltage in Volts while generating hydrogen and oxygen. Record your answers below:

(Answers will vary, but check that they are within reason, i.e. not 100V or >1A.)

Current: _____ A

Voltage: _____ V

2. Voltage is equal to the current multiplied by the resistance (V = IR), so according to your data what is the resistance of the fuel cell?

Resistance:_____ Ω

3. Measure the current in Amps and the voltage in Volts while the car is running. Record your answers below:

Current: _____ A

Voltage: _____ V

4. Why is there a difference between the current/voltage when producing hydrogen and the current/voltage when the car is running? Where has the energy gone?

Not all the energy has gone into the hydrogen during the electrolysis process, and not all the energy has gone into the car's motion while it's driving. Heat, friction, light, sound, and other sources of energy loss could be mentioned.

Energy Conservation and Transformation

Analysis

1. Make a scientific claim about what you observed while running the fuel cell car.

Claim should reference energy use, transformation, and/or conservation in the running car.
Example: "A smoother surface allows the car to run for a longer time."

2. What evidence do you have to back up your scientific claim?

Evidence should cite data in Observations and/or Experimentation sections.
Example: "On the tile floor, our car ran for 26 seconds. On the carpet, our car only ran for 14 seconds."

3. What reasoning did you use to support your claim?

Reasoning can draw from Background section and/or other materials used in class.
Example: "A smoother surface would reduce friction, a force that we learned opposes motion."

4. Use your observations to design an experiment you could run to try to increase the energy efficiency of the fuel cell. Describe your experiment below.

Change pressure/temperature of the water/gases, construct it with different materials, decrease the weight of the car, reduce friction, and more are all ideas that could be tested. Students should identify control and experimental setups, and define the variable to be tested.

Energy Conservation and Transformation

Conclusions

1. What kinds of energy did you observe while running your experiments with the fuel cell car?

Kinetic, Chemical, Potential, Sound, Electrical, and others may be acceptable answers.

2. Describe the ways that energy changed from one form to another during this activity.

Chemical energy in the battery became electrical energy in the wires, which became chemical energy in the hydrogen, which became electrical energy in the wires, which became kinetic energy in the motor, and others may be acceptable answers.

3. Describe three ways that energy was transformed that didn't help your car move faster or farther.

Lights lit up, motor made noise, friction of wheels on ground, friction of motor with axle/wheels, vibrations of motor, and others may be acceptable answers.

4. Would it ever be possible to use 100% of the electric energy produced by the fuel cell to move the car? Why or why not?

No, because that would only be possible in frictionless environment, violating law of conservation of energy.